A Prototype Water Vapor Flux Tool for Precipitation Forecasting

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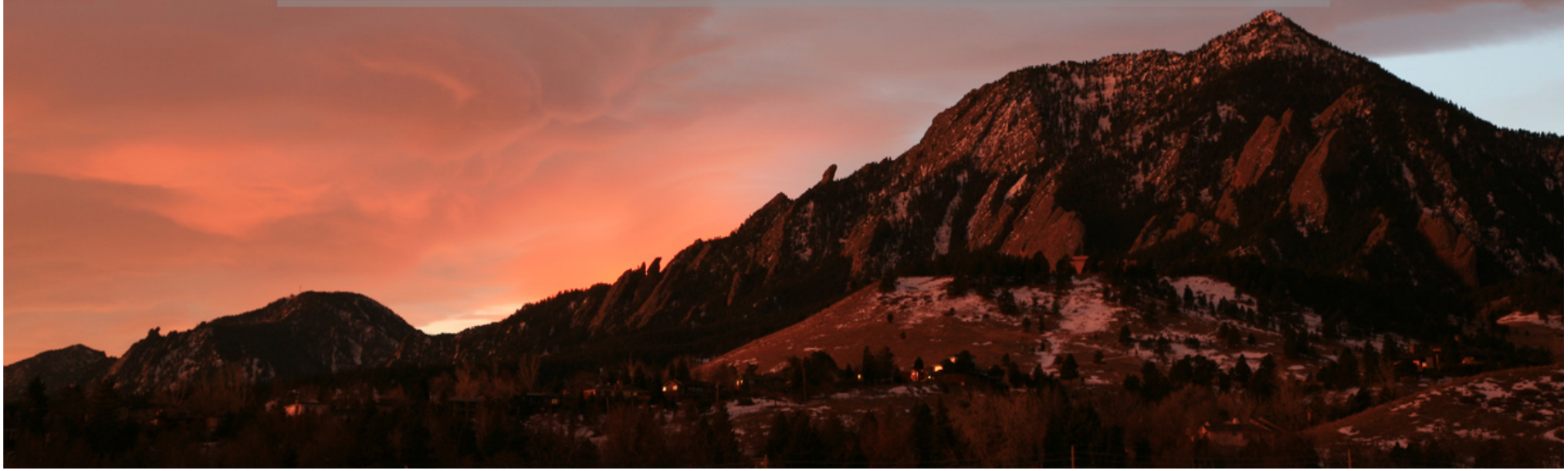


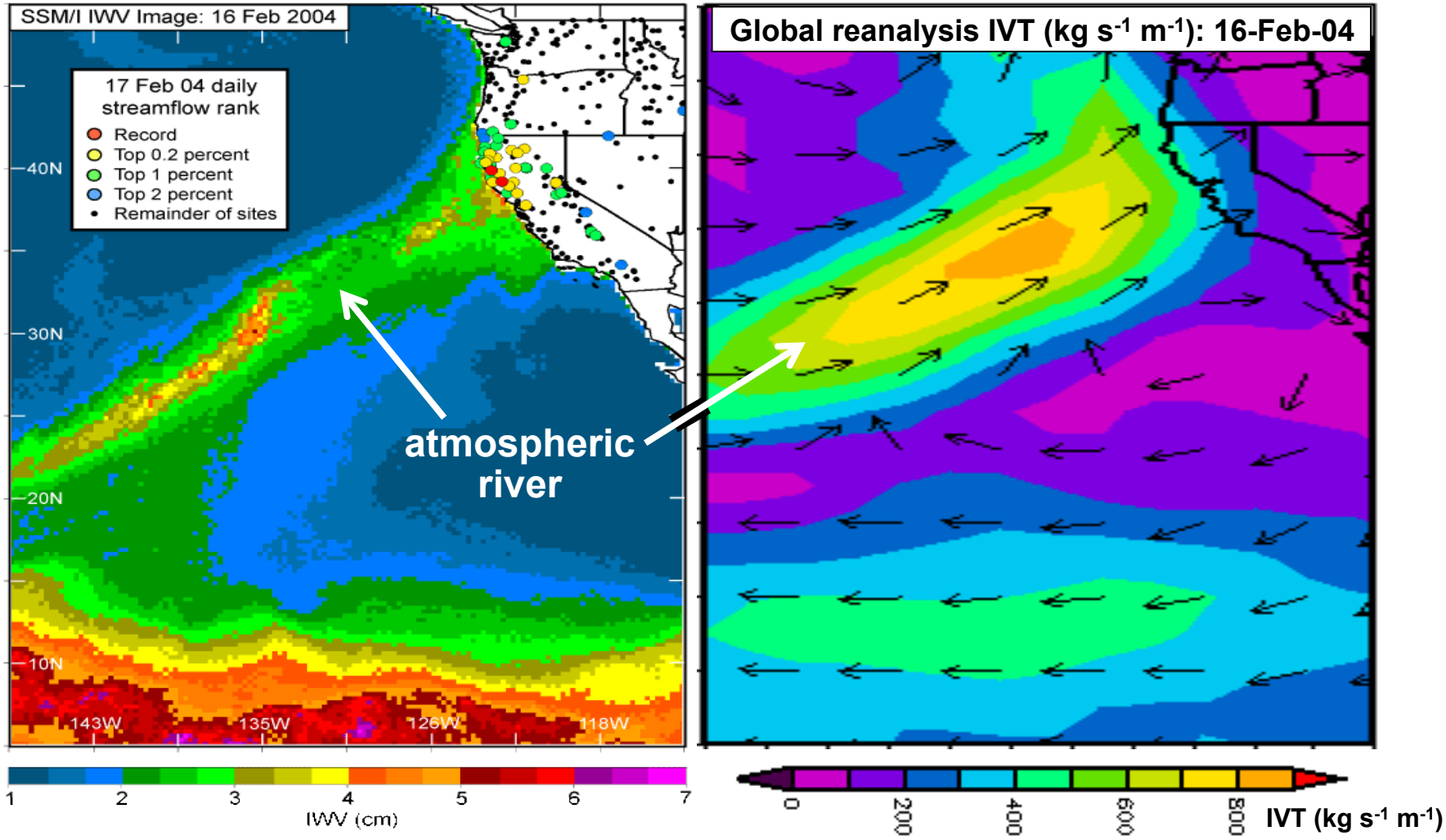
Purpose and Outline

Purpose: To describe the development of a prototype real-time observation and model forecast evaluation tool of low-level water vapor flux as a key determinant of orographic precipitation in extreme events.

Outline

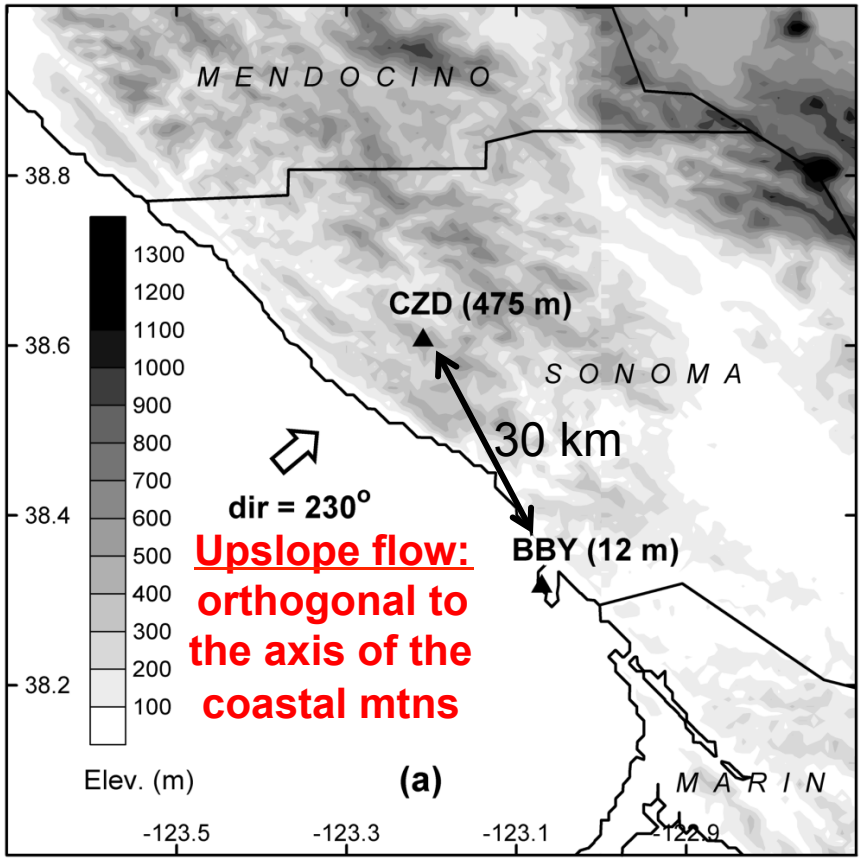
- Background
- Observing system configuration
- Comparison with mesoscale model forecast
- UMF tool implementation status
- Conclusions

- Heavy cool-season rain & flood events along the U.S. West Coast are orographically driven and occur most often when narrow warm-sector corridors of strong water-vapor transport (i.e., atmospheric rivers – ARs) intersect the coastal mountains (e.g., Ralph et al. 2006 in *GRL*; Neiman et al. 2008 in *JHM*).



Wintertime orographic forcing climatology along northern California coast

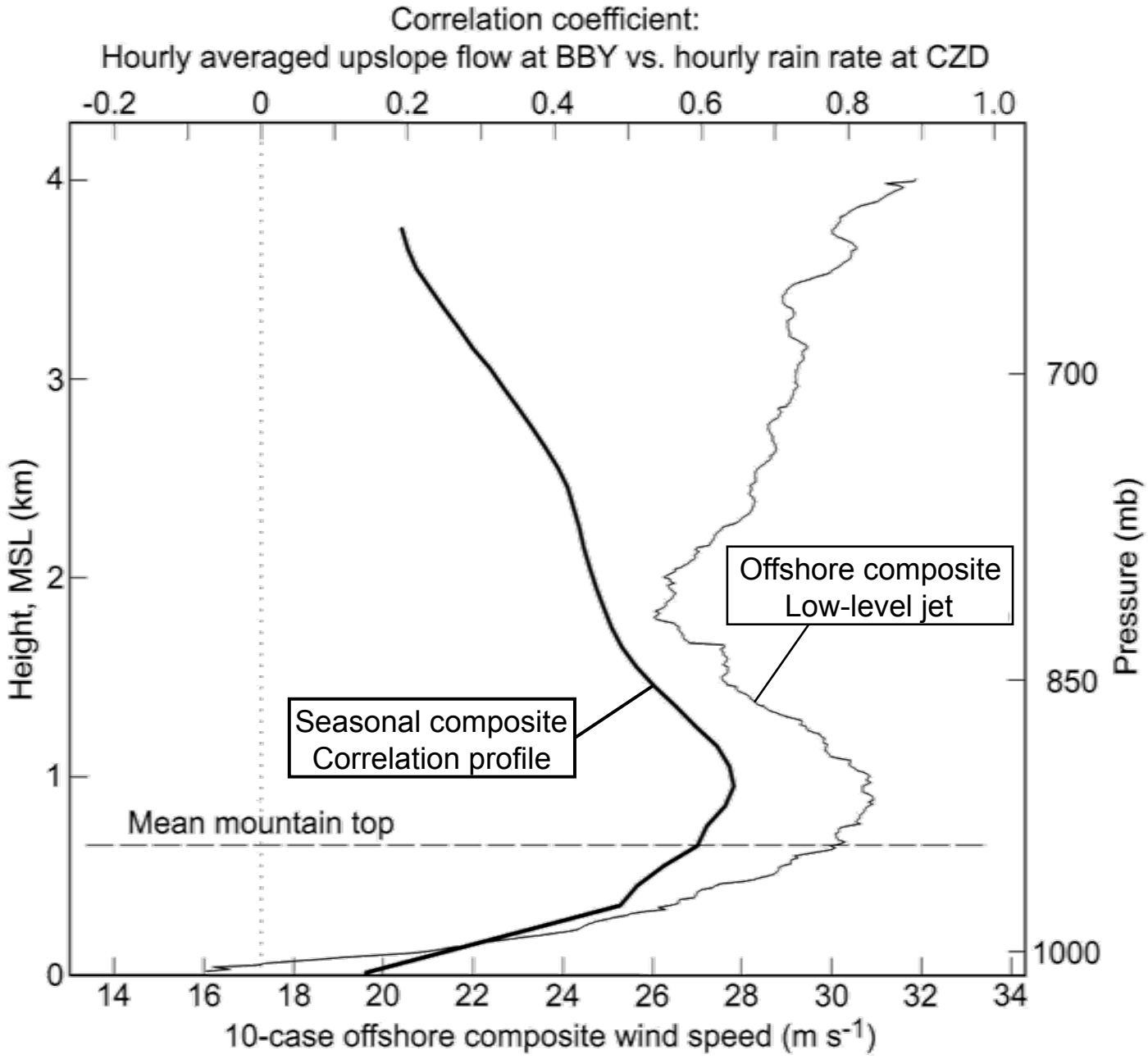
Developed real-time monitoring of vapor transports to assess the orographic forcing, based on published research using wind profilers, as well as GPS receivers that measure IWV

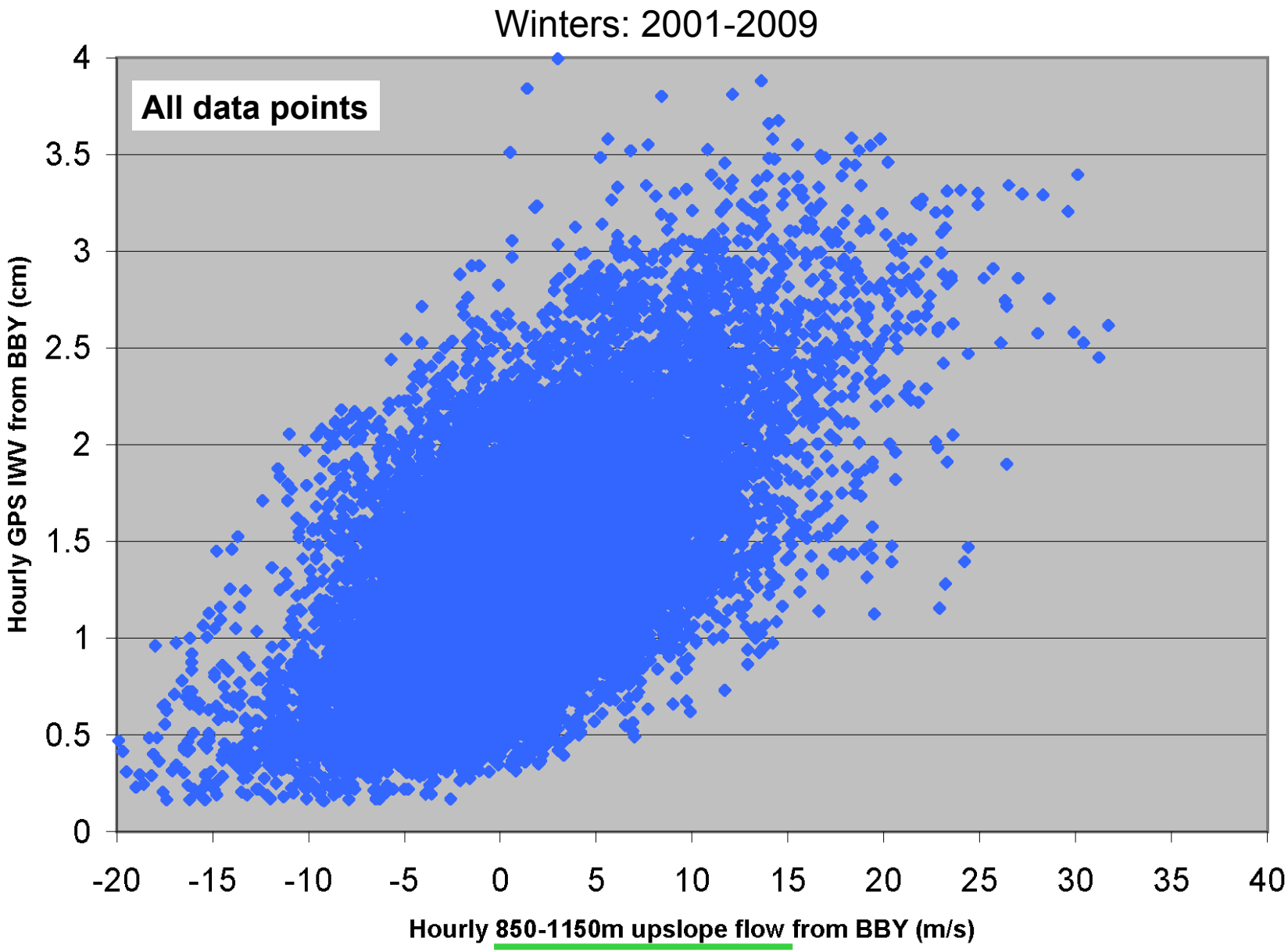


Neiman et al. (2002), *Mon. Wea. Rev.*

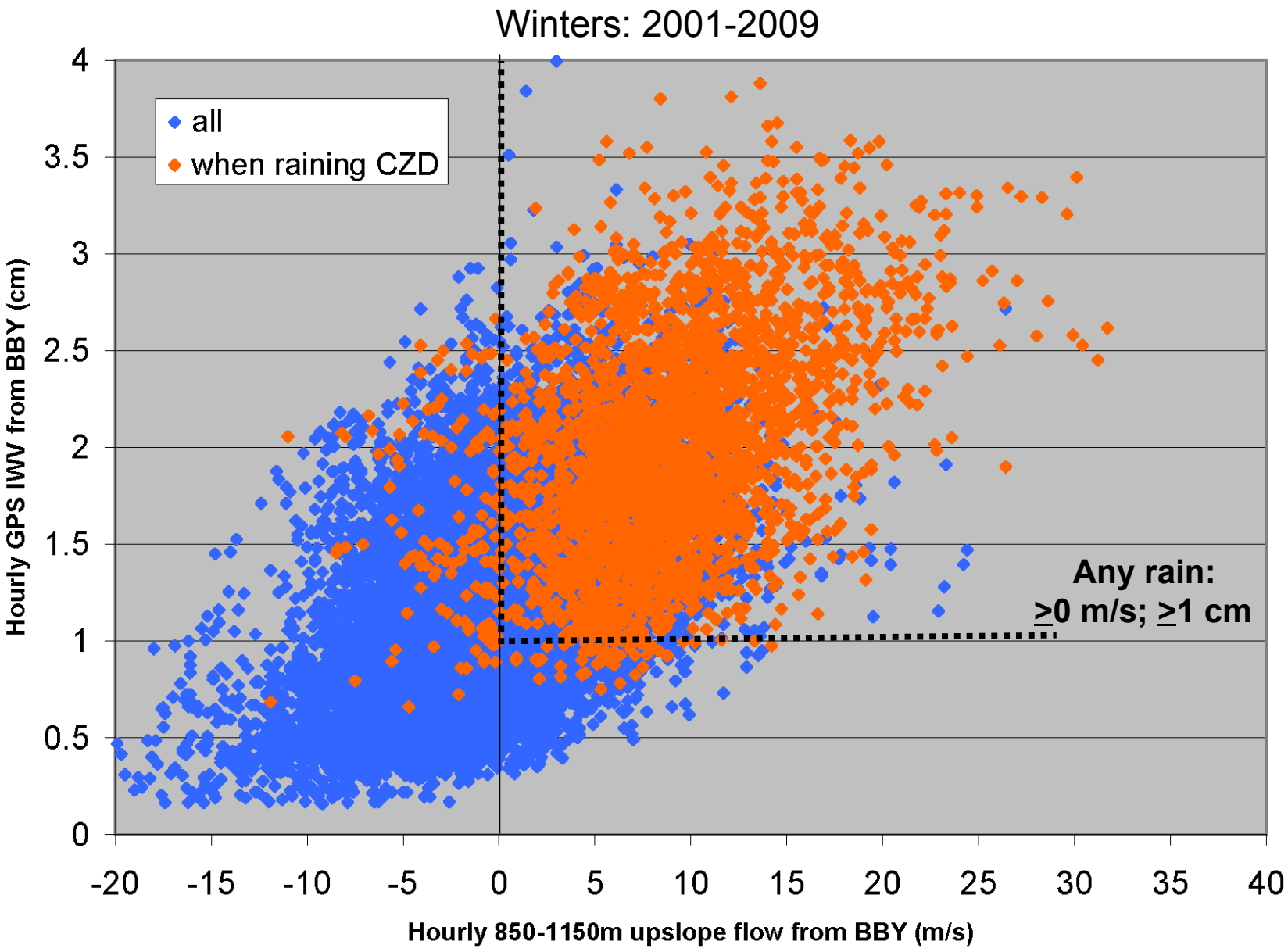
- Flood-prone Russian River Basin northwest of San Francisco: 2000/01, 2003/04, 2004/05, 2005/06, 2006/07, 2007/08, 2008/09
- Analyses for when the following observing systems were simultaneously operating – (a) Bodega Bay (BBY): GPS-IWV unit, 915-MHz wind profiler, rain gauge (b) Cazadero (CZD): rain gaugeTotal precip: CZD=6857 mm, BBY=2761 mm (ratio 2.48:1)
- 18347 hourly data points

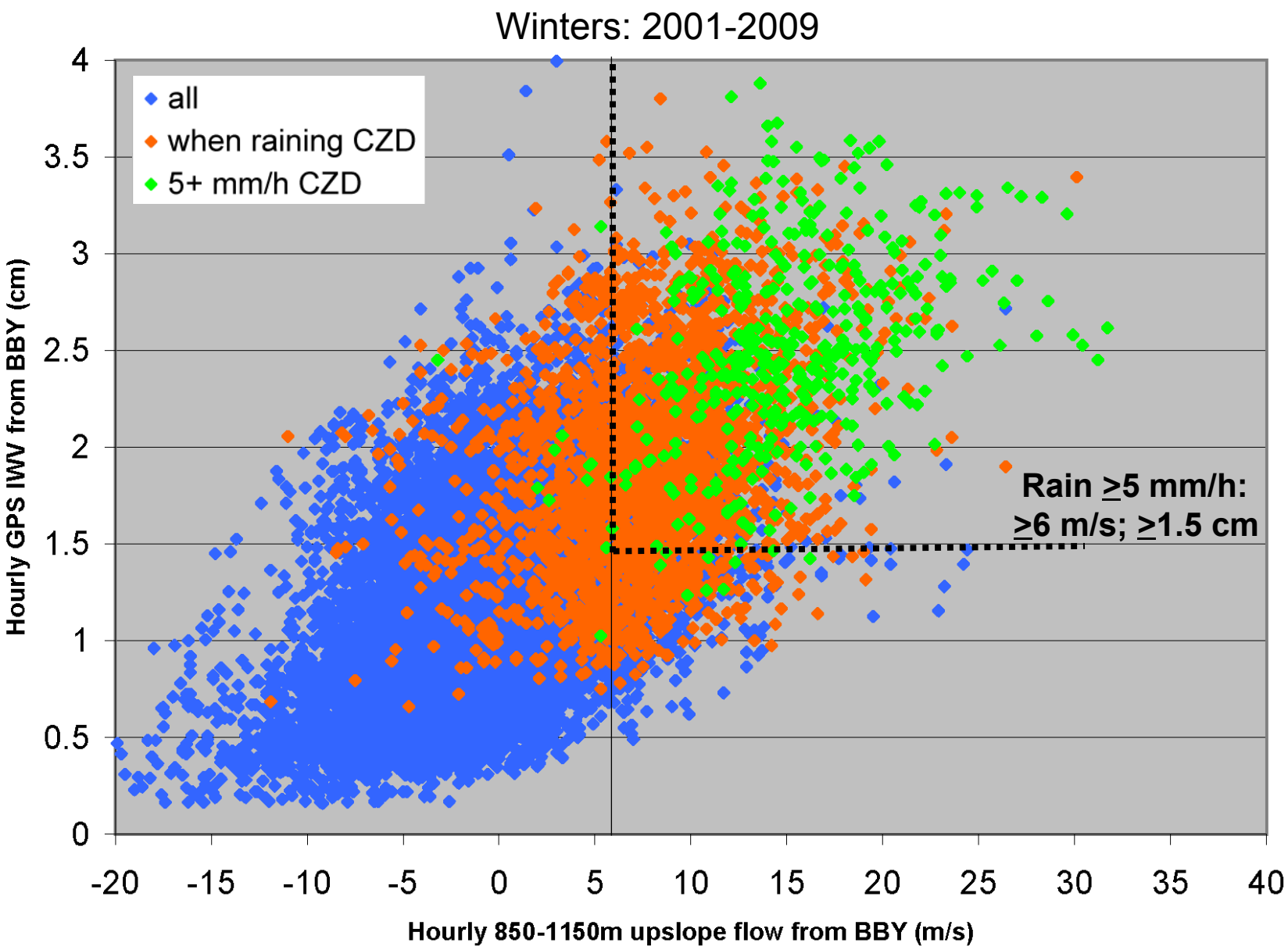
Neiman et al. (2008), *Water Management*

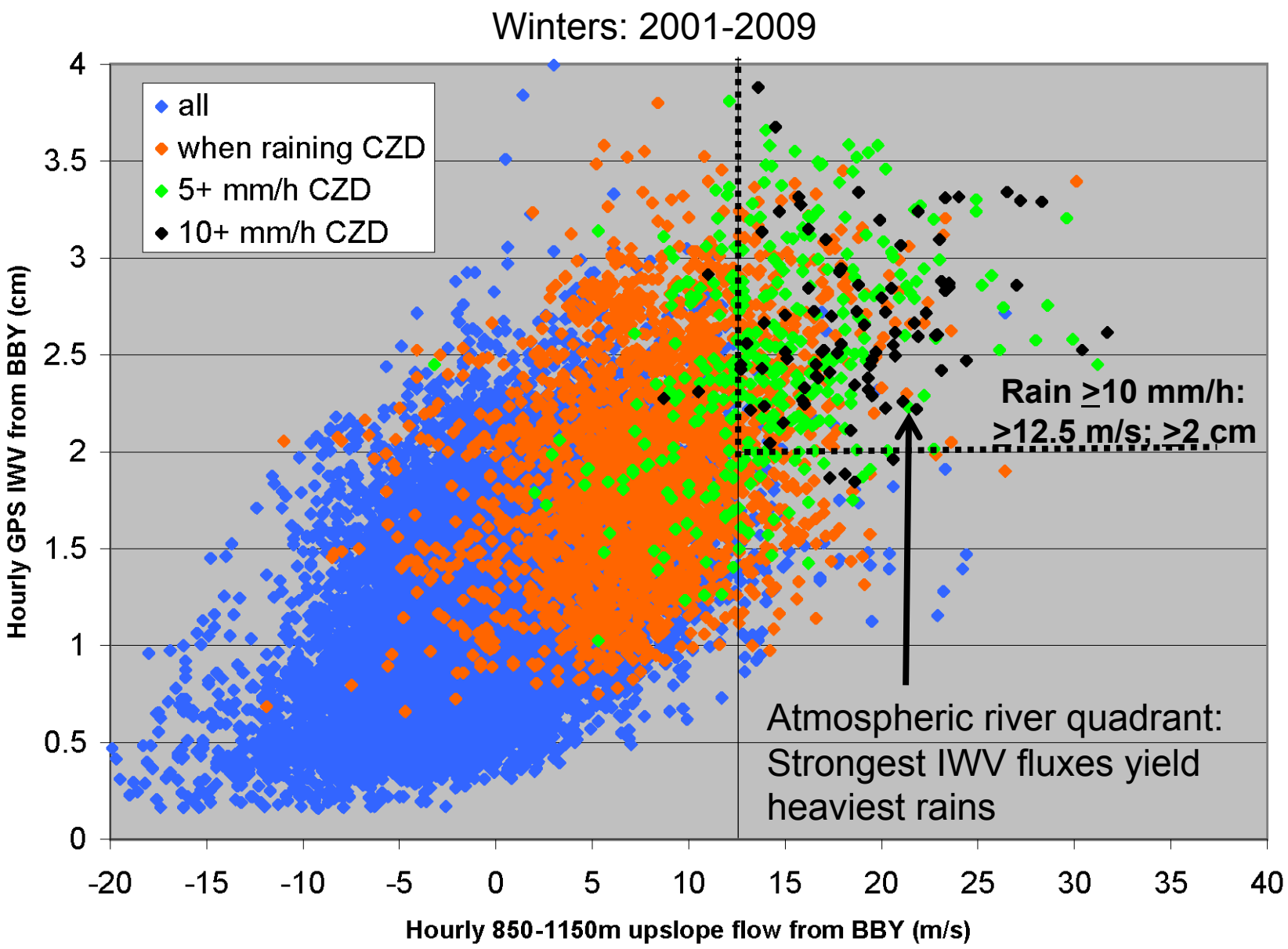

Correlation coefficient:
Hourly averaged upslope flow at BBY vs. hourly rain rate at CZD
-0.2
0
0.2
0.4
0.6
0.8
1.0
Height, MSL (km)
4
3
2
1
0
Pressure (mb)
700
850
1000
Offshore composite
Low-level jet
Seasonal composite
Correlation profile
Mean mountain top
14
16
18
20
22
24
26
28
30
32
34
10-case offshore composite wind speed (m s-1)



Component of the flow in the orographic controlling layer directed from 230°, i.e., orthogonal to the axis of the coastal mtns

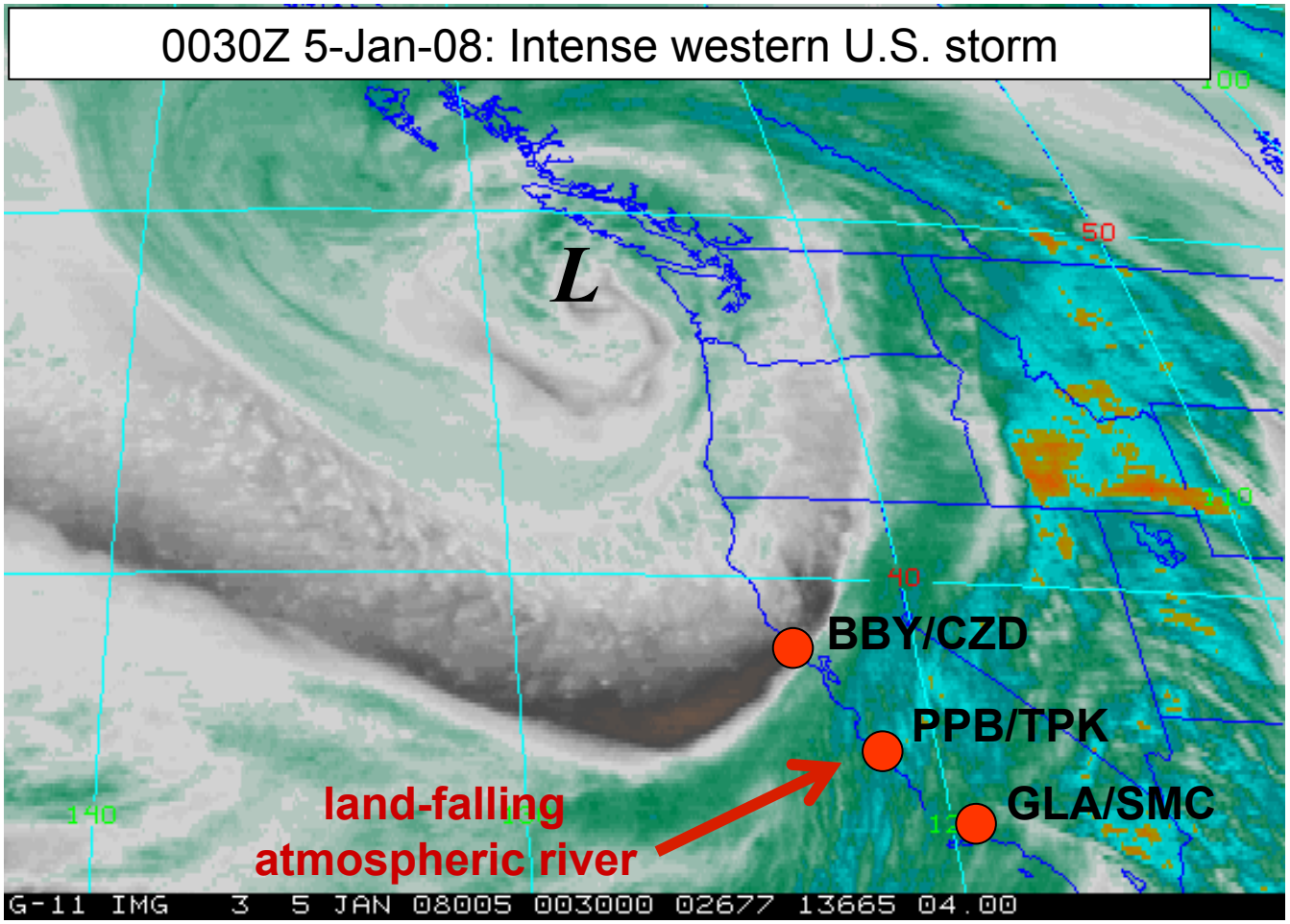

Winters: 2001-2009
all
when raining CZD
Any rain:
≥0 m/s; ≥1 cm
Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40


Winters: 2001-2009
all
when raining CZD
5+ mm/h CZD
Rain ≥5 mm/h:
≥6 m/s; ≥1.5 cm
Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40



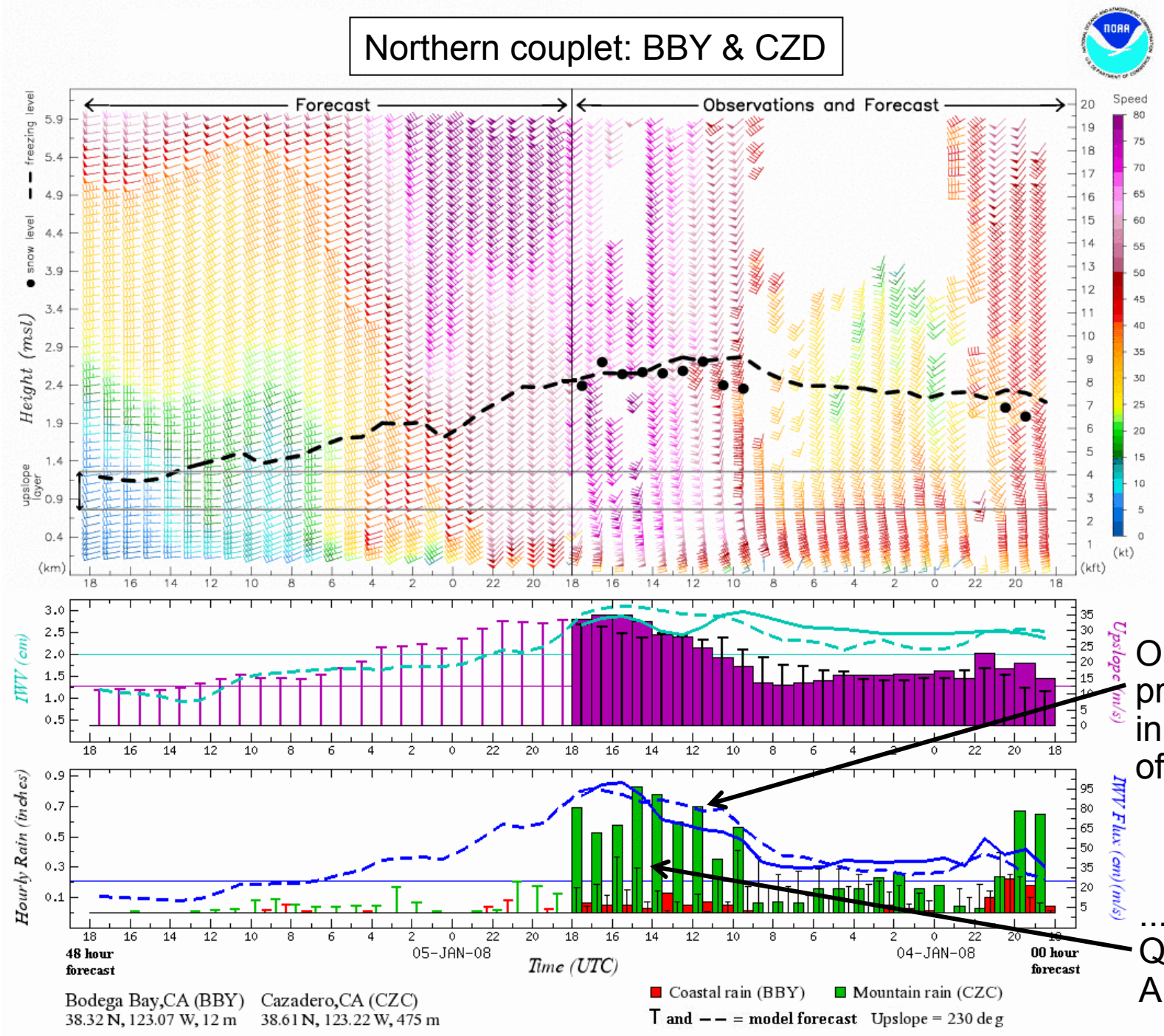
*Nearly 2/3 of tropospheric water vapor is in the lowest 2 km MSL.
Hence, to first order, the IWV flux provides a close estimate
of the low-level water-vapor transport into the coastal mountains.

Prototype forecast tool tested at 3 CA couplets during NOAA's HMTs



Couplet	**Coast** (*profiler, GPS, rain gauge*):	**Mountains** (*rain gauge*):
North:	Bodega Bay (BBY; 12 m MSL)	Cazadero (CZD; 475 m MSL)
Central:	Piedras Blancas (PPB; 11 m MSL)	Three Peaks (TPK; 1021 m MSL)
South:	Goleta (GLA; 3 m MSL)	San Marcos Pass (SMC; 701 m MSL)

Northern couplet: BBY & CZD

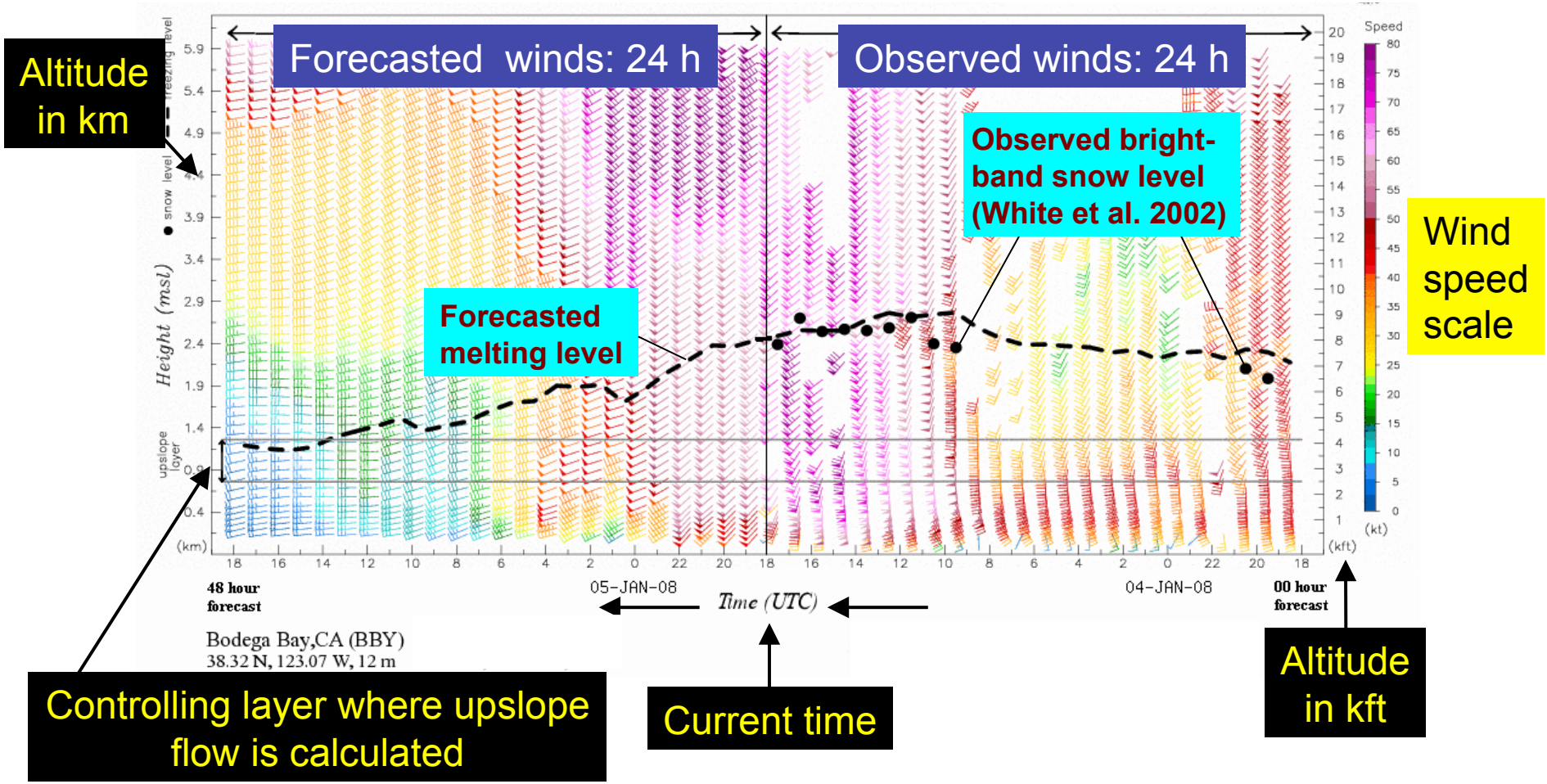


Orogr. forcing predicted well in this portion of the AR...

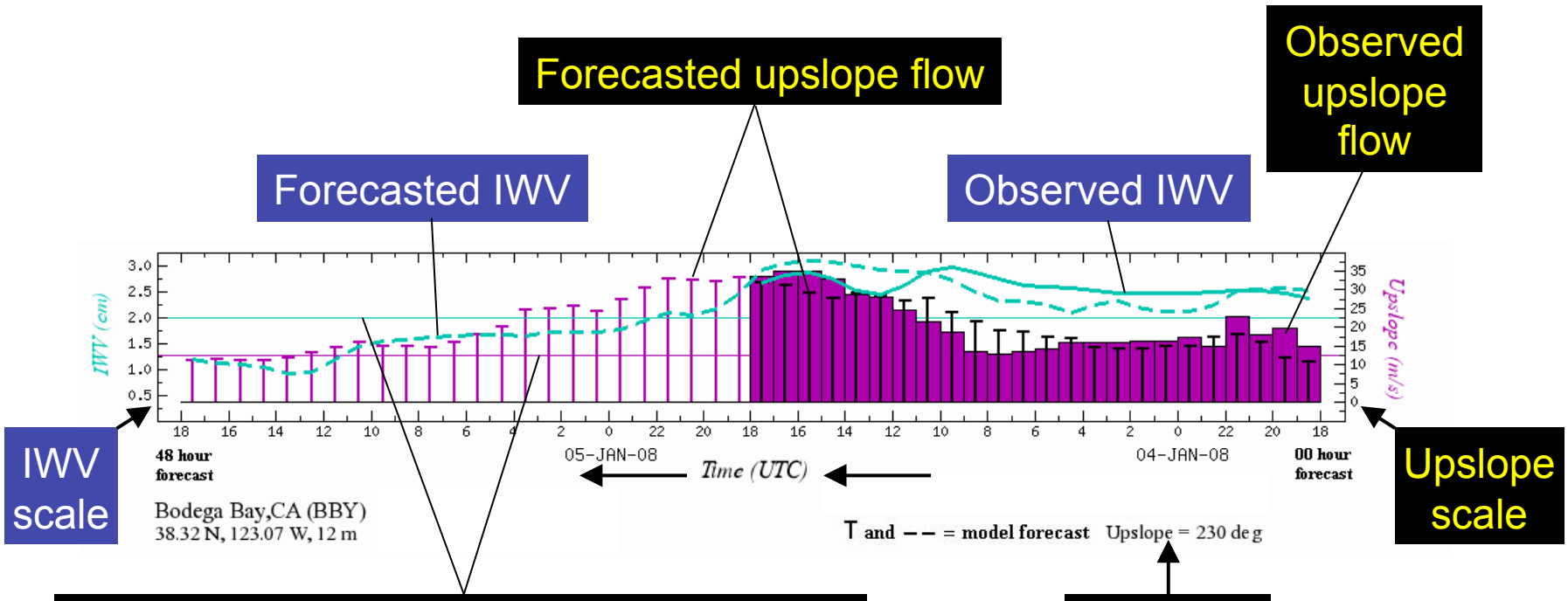
...but not the QPF, esp. in AR conditions.

The top of three panels of the forecast tool displays hourly wind profiles and snow levels

Model: Advanced Research WRF (ARW), 48-h duration
Grid configuration: 3 km horizontal, 30 vertical levels



The middle panel displays the upslope component of the flow and the IWV



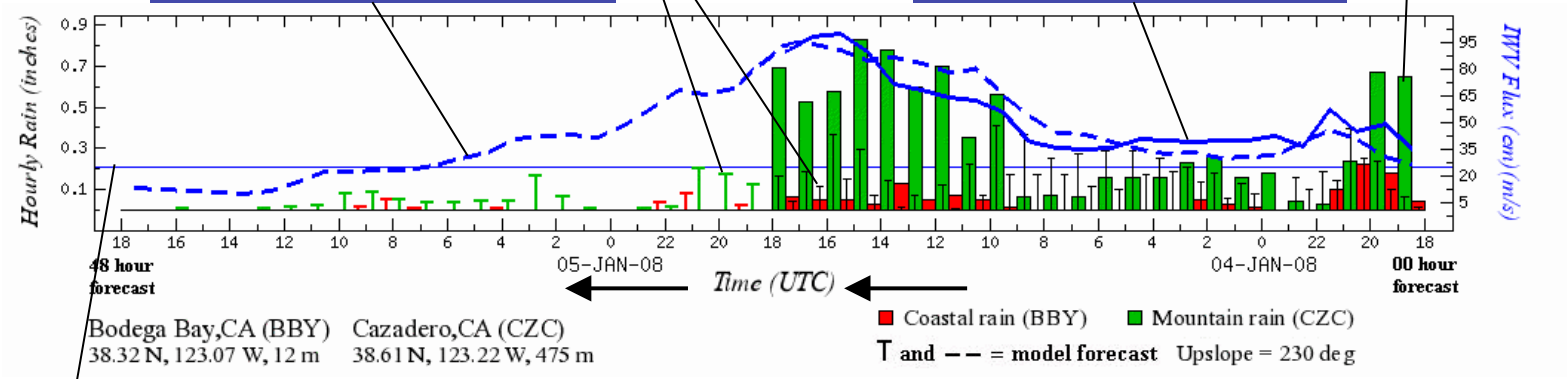
The IWV and upslope flow from the middle panel are combined to produce a bulk IWV flux, which is displayed in the bottom panel along with the coastal and mountain hourly rainfall

Forecasted rainfall (T posts):
Red = coastal site
Green = mountain site

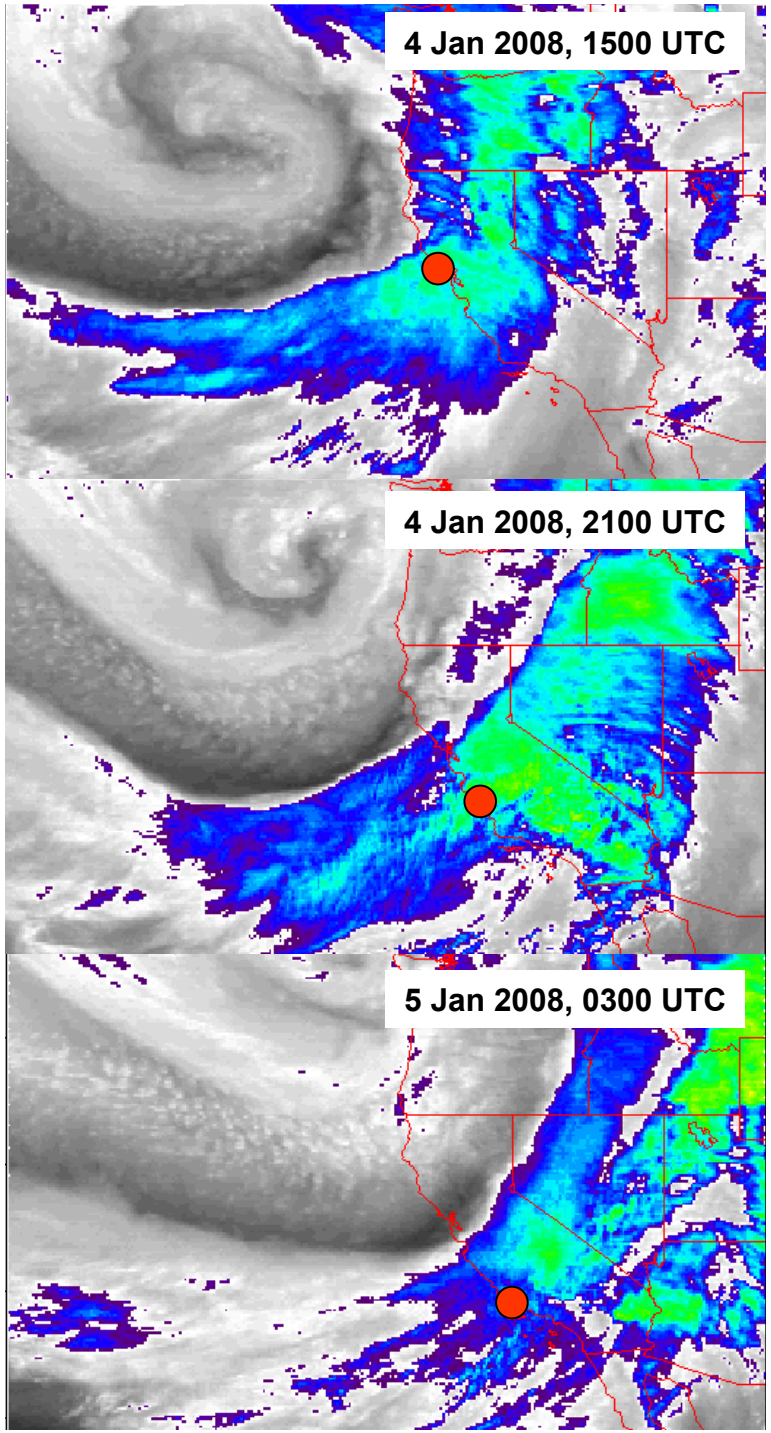
Observed rainfall (bars):
Red = coastal site
Green = mountain site

Forecasted IWV flux

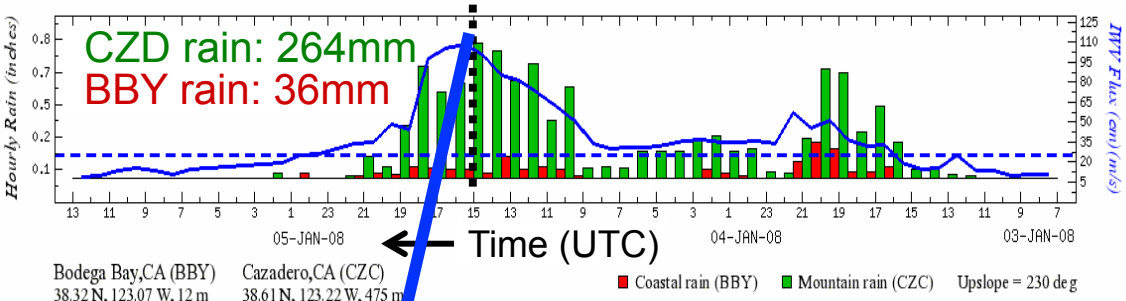
Observed IWV flux



The thin blue horizontal line gives the IWV flux threshold (25 cm x m s^{-1}) determined by multiplying the IWV and upslope flow thresholds defined in the middle panel

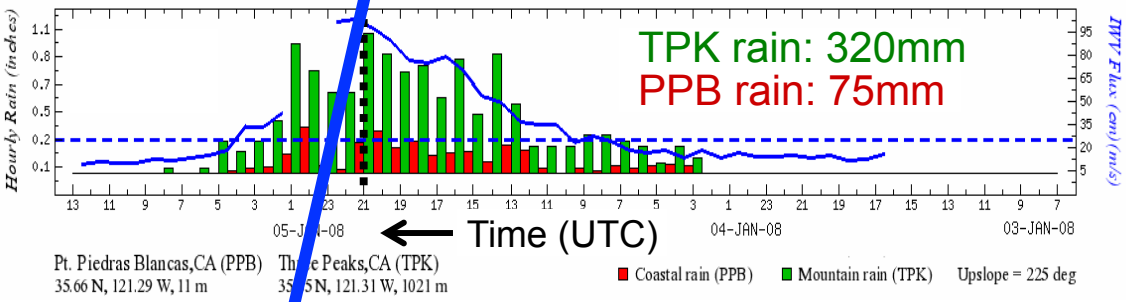


Time of max. IWV flux at BBY: 1500 UTC 4-Jan-08



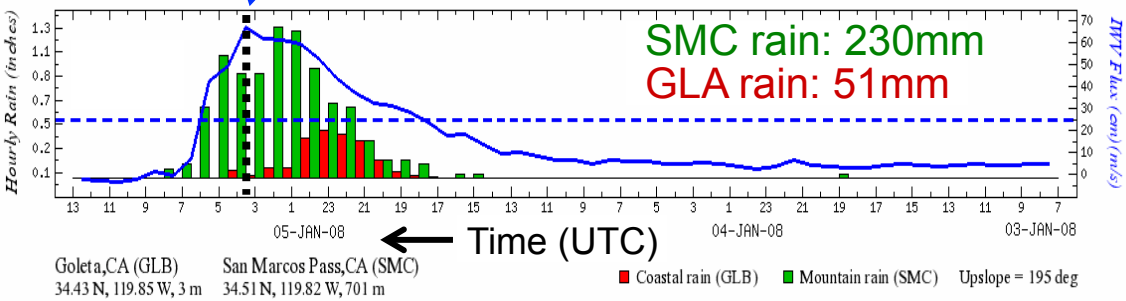
Max. IWV flux in AR highly correlated with max. mountain rainfall at each site

Time of max. IWV flux at PPB: 2100 UTC 4-Jan-08



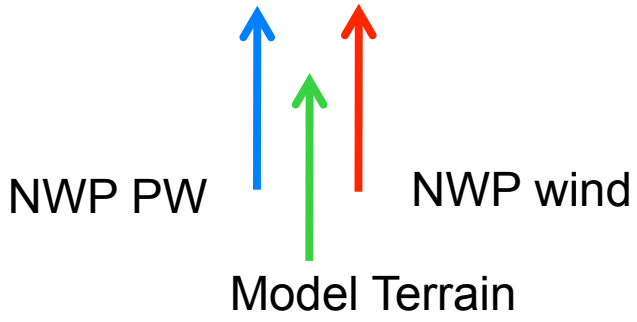
AR Propagation: ~12 m s^{-1}. ½-day lead time for SoCal

Time of max. IWV flux at GLA: 0300 UTC 5-Jan-08



Prototype UMF Tool Implementation

UM Flux = (q x v) @ 1 km MSL

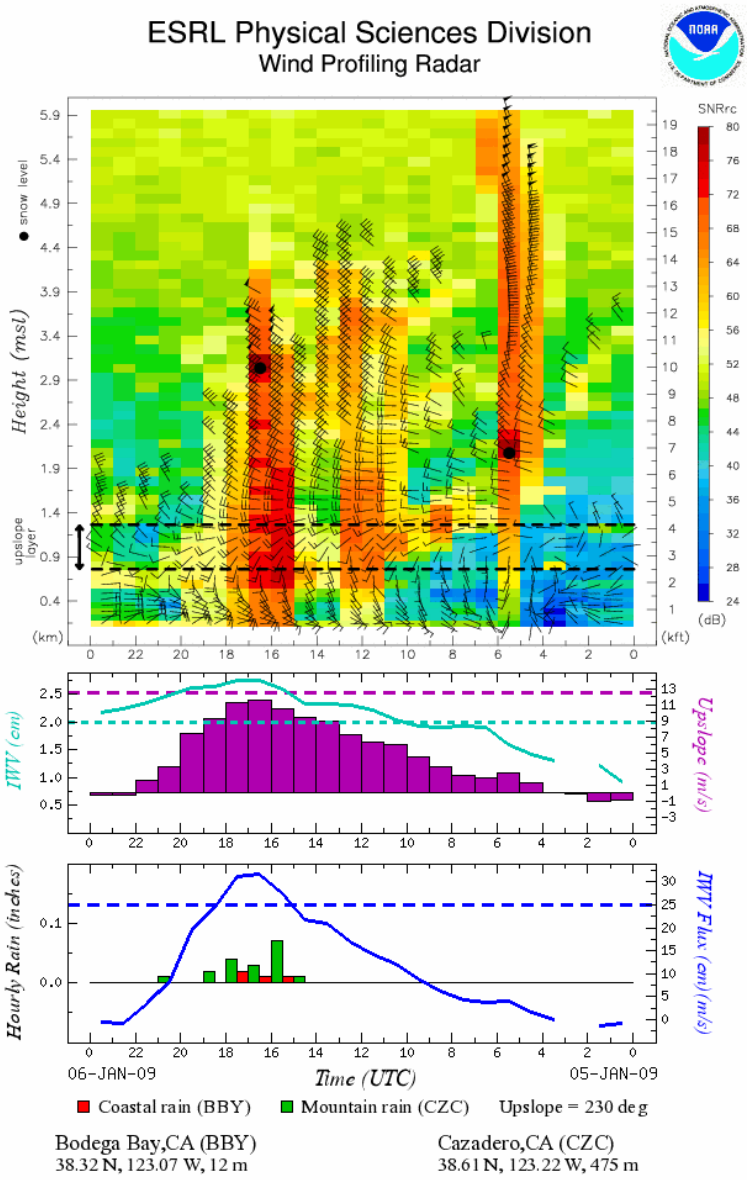


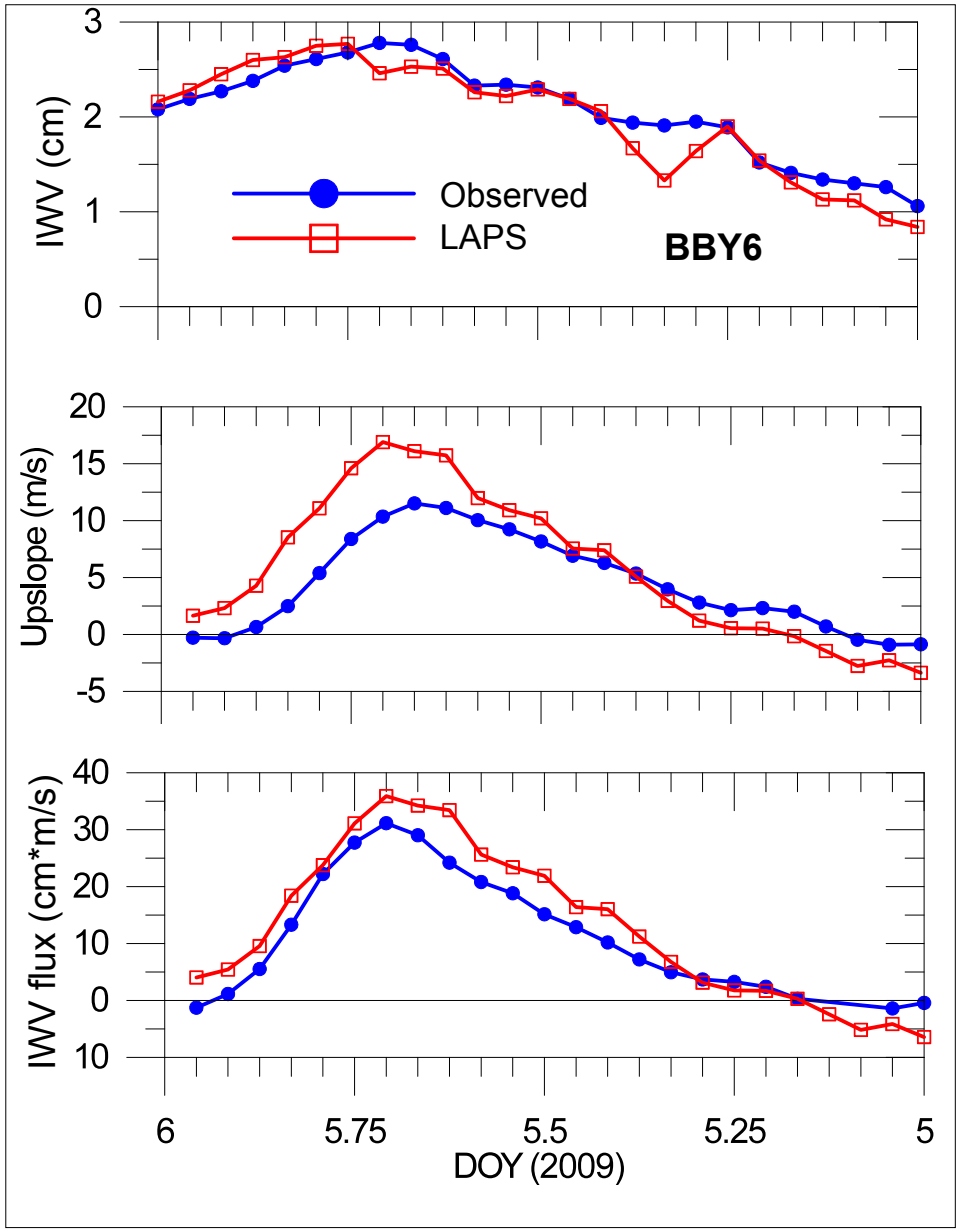
Utility as a forecast tool is depended on:

NWP pw vs Obs (gps) pw correlation

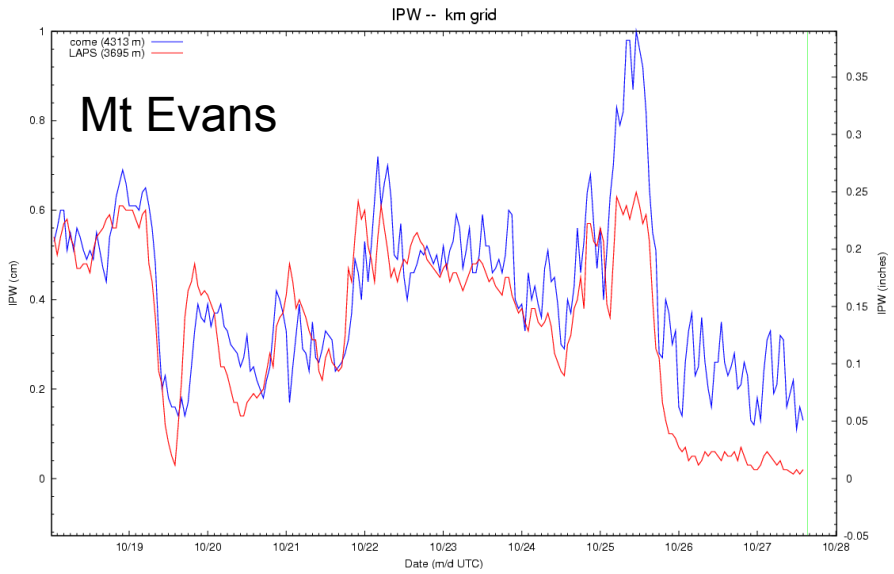
NWP wind speed vs profiler wind speed correlation

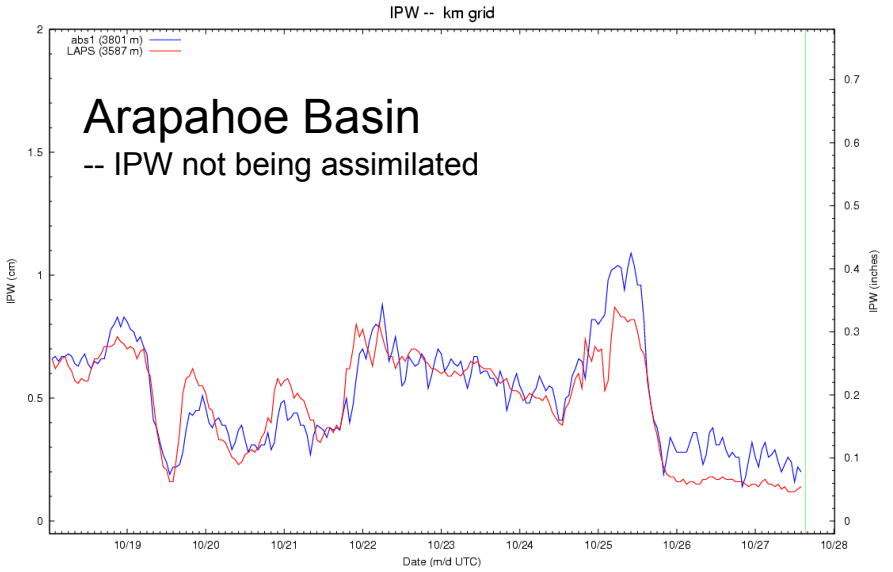
Local Analysis and Prediction System (LAPS; 9.9 km resolution)
Verifying model against observations at Bodega Bay, CA

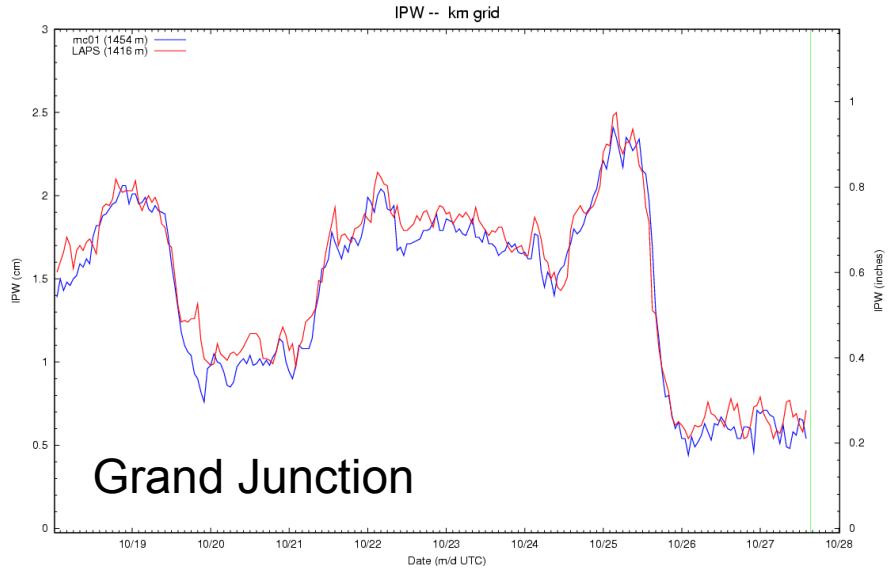


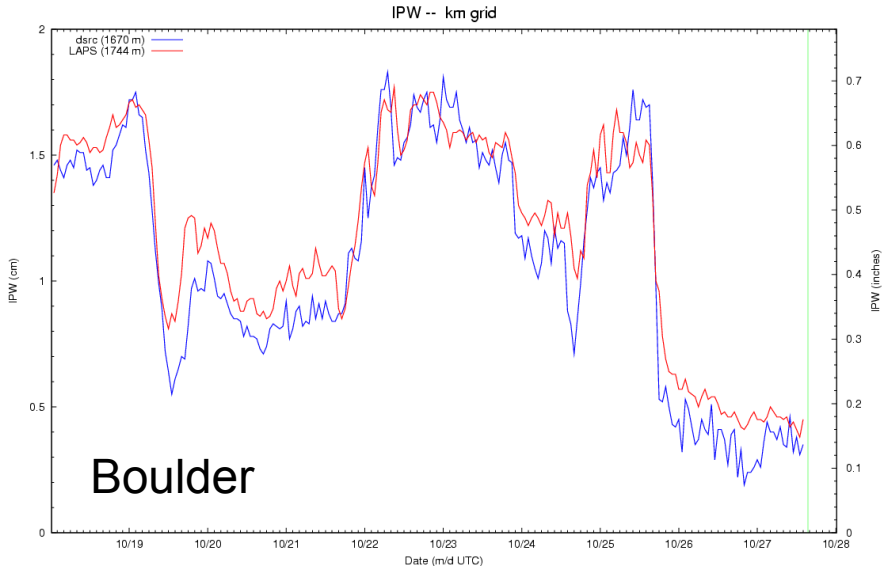


LAPS Analysis vs GPS IPW

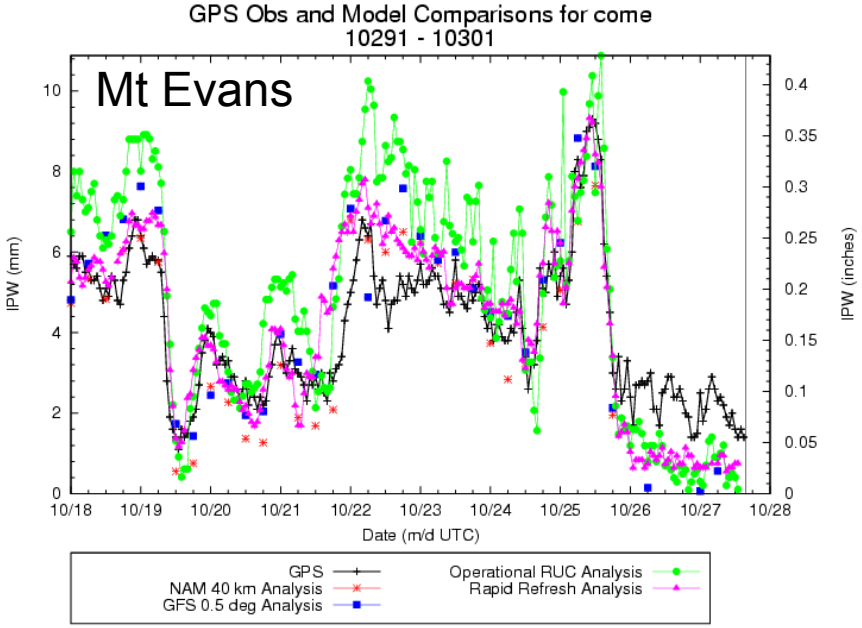


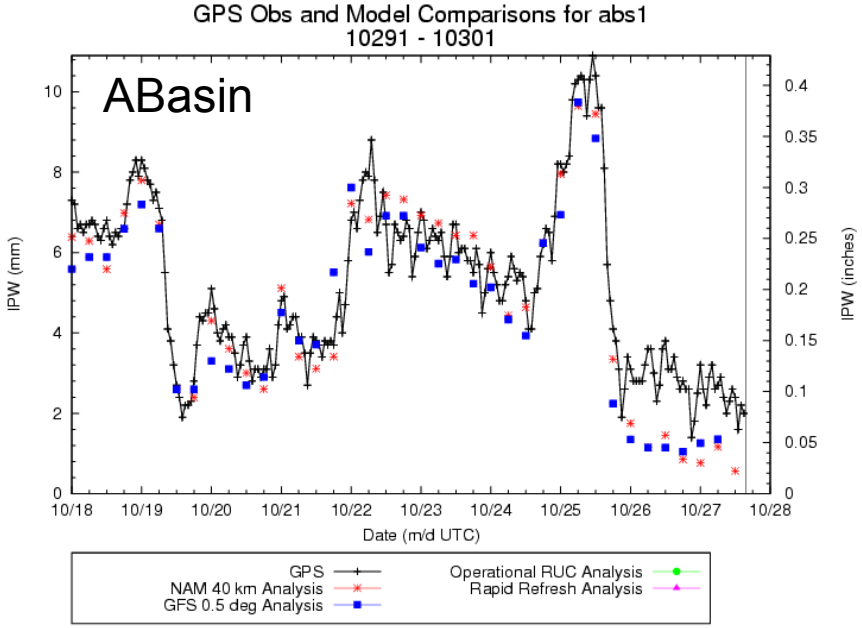


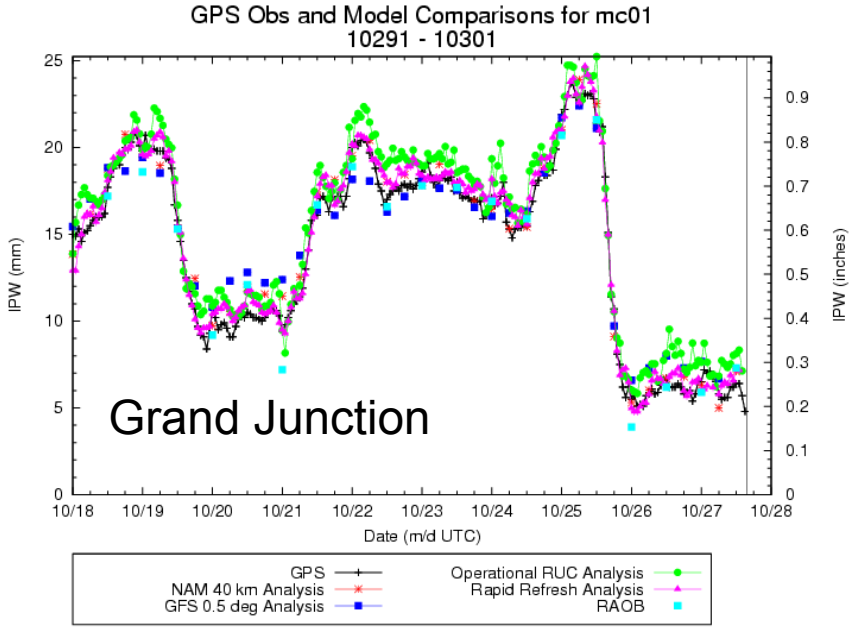


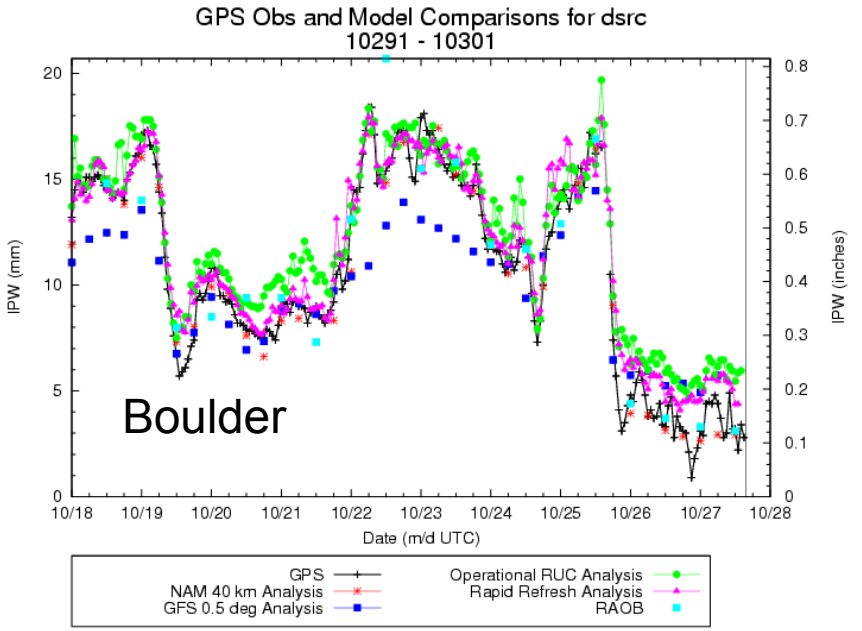


NWP Analysis vs GPS IPW

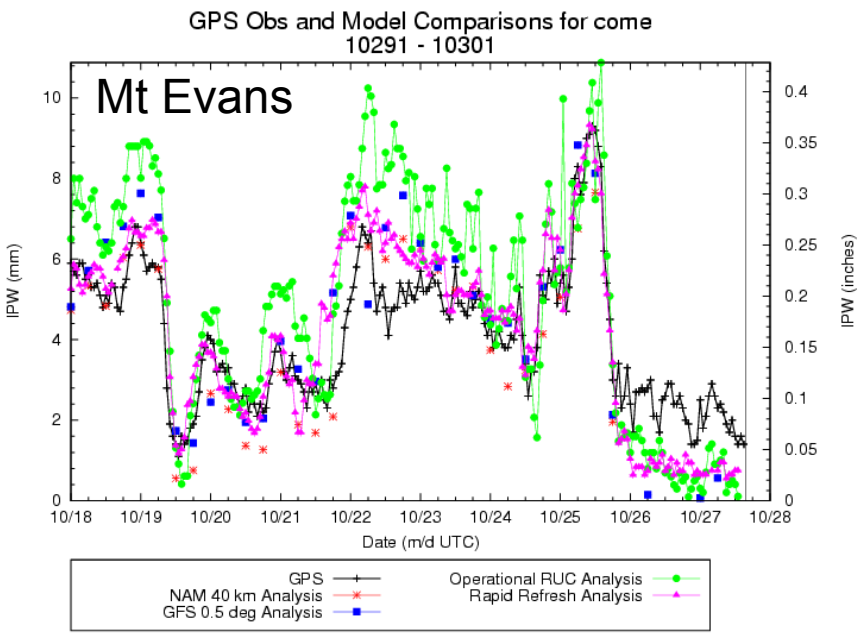


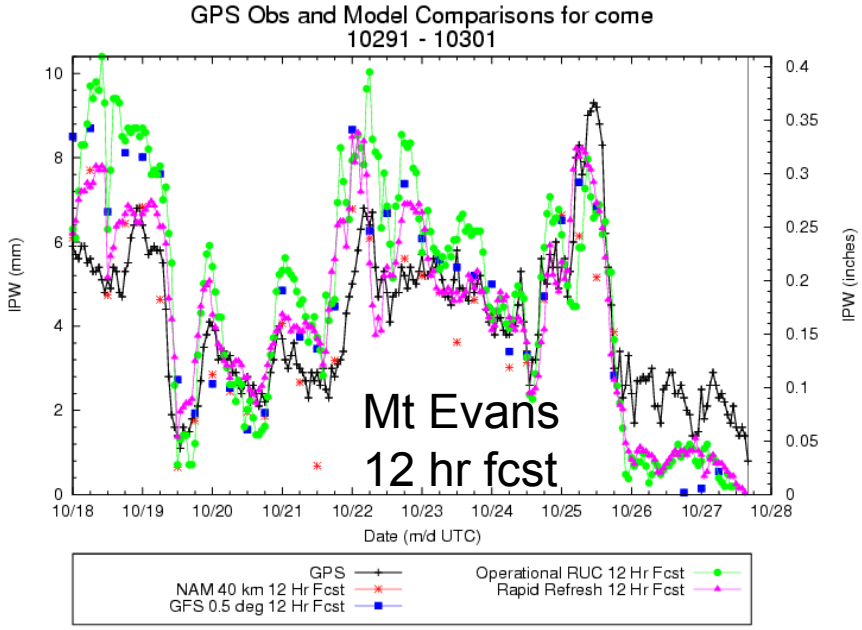


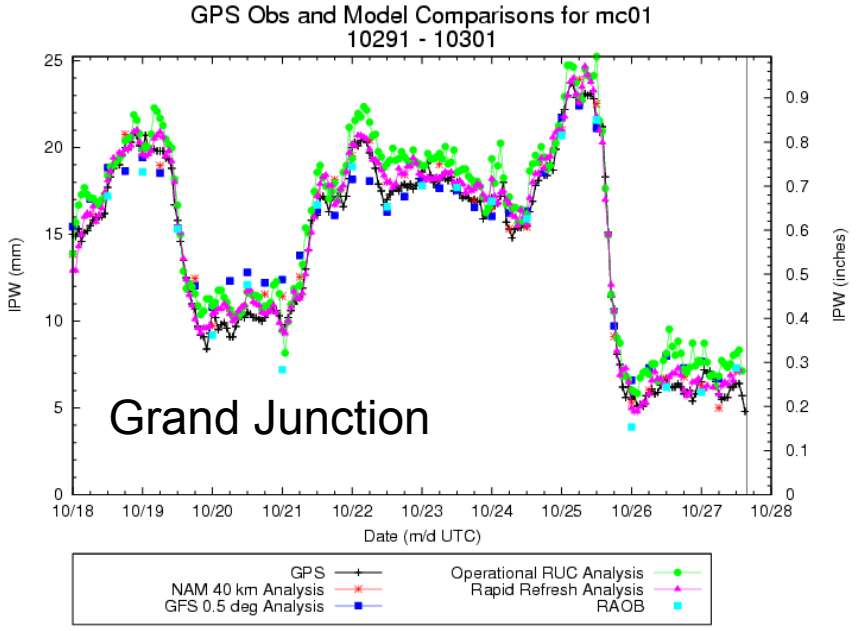


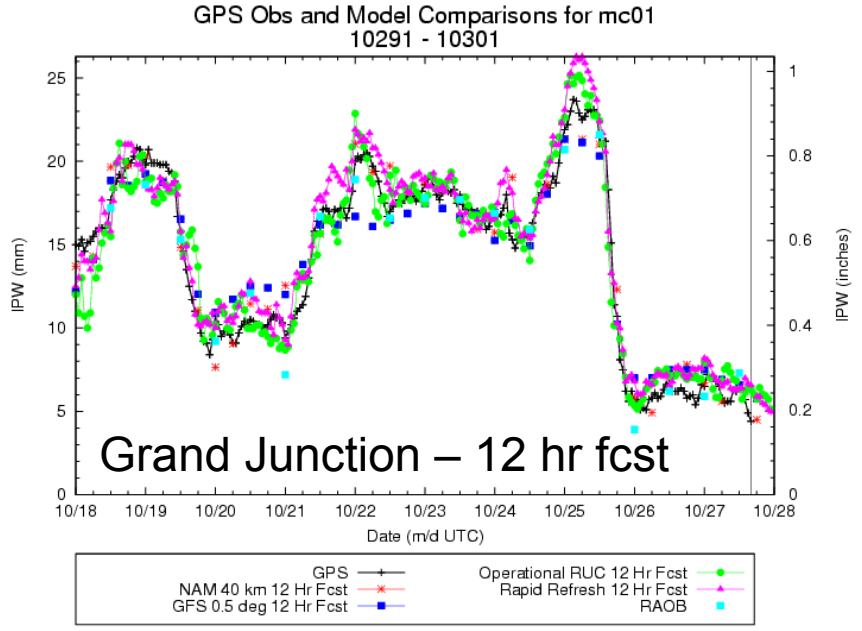


NWP Forecast vs GPS IPW

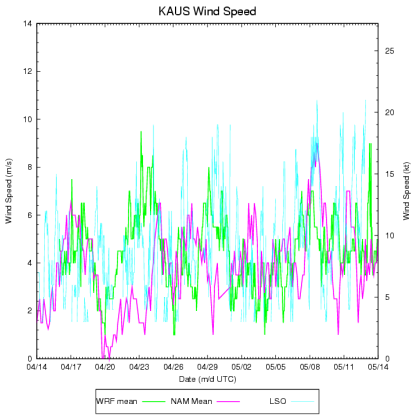


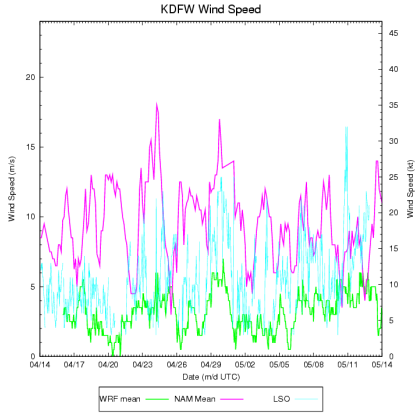


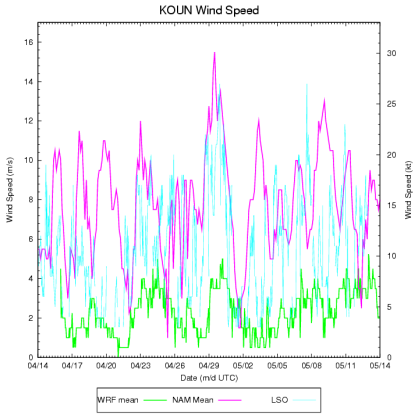


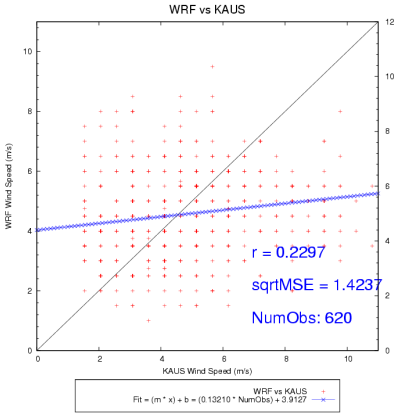


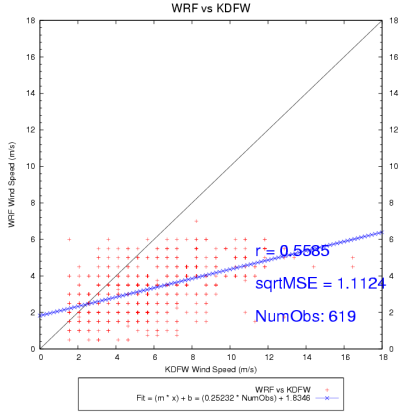
NWP vs Obs wind speed

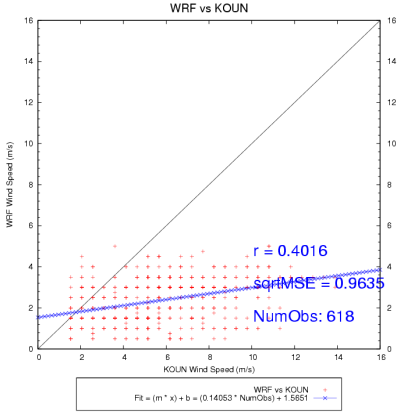


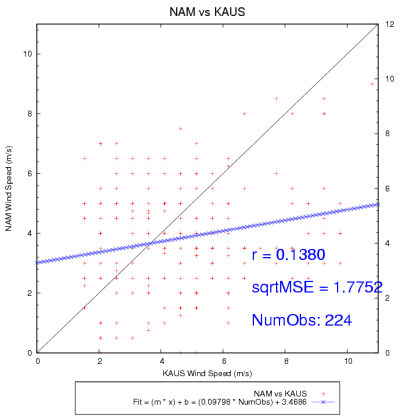


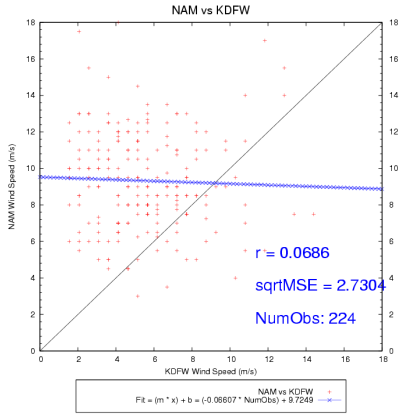


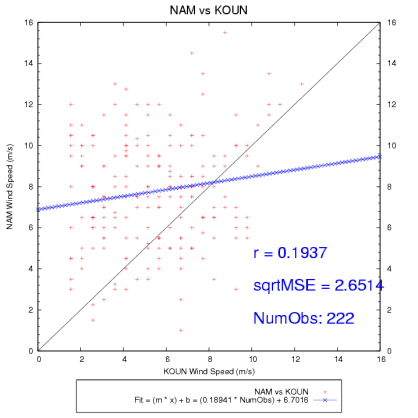






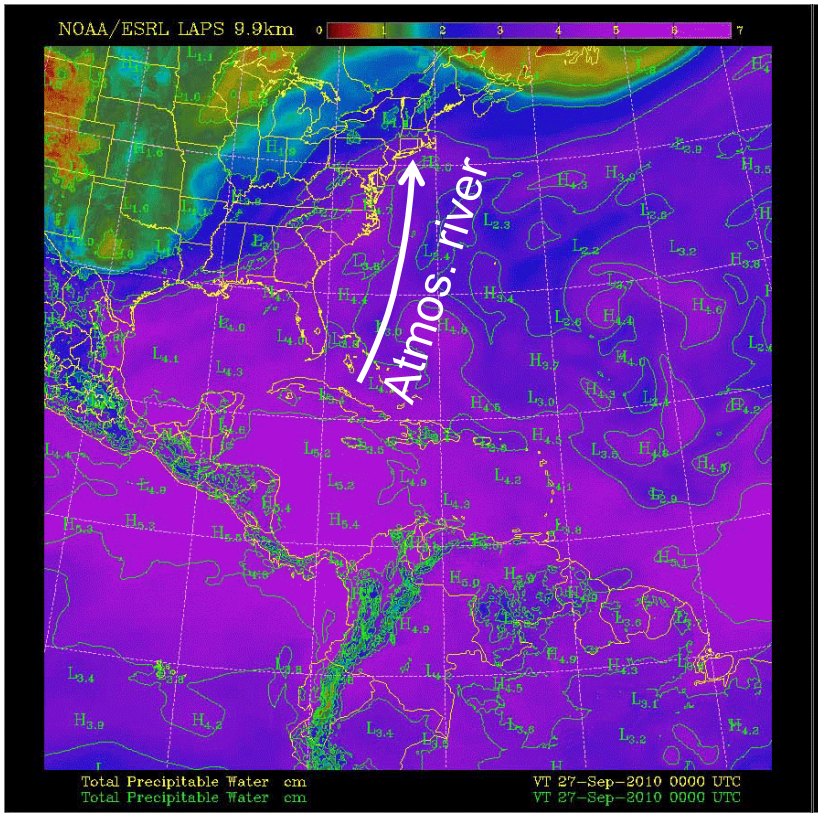




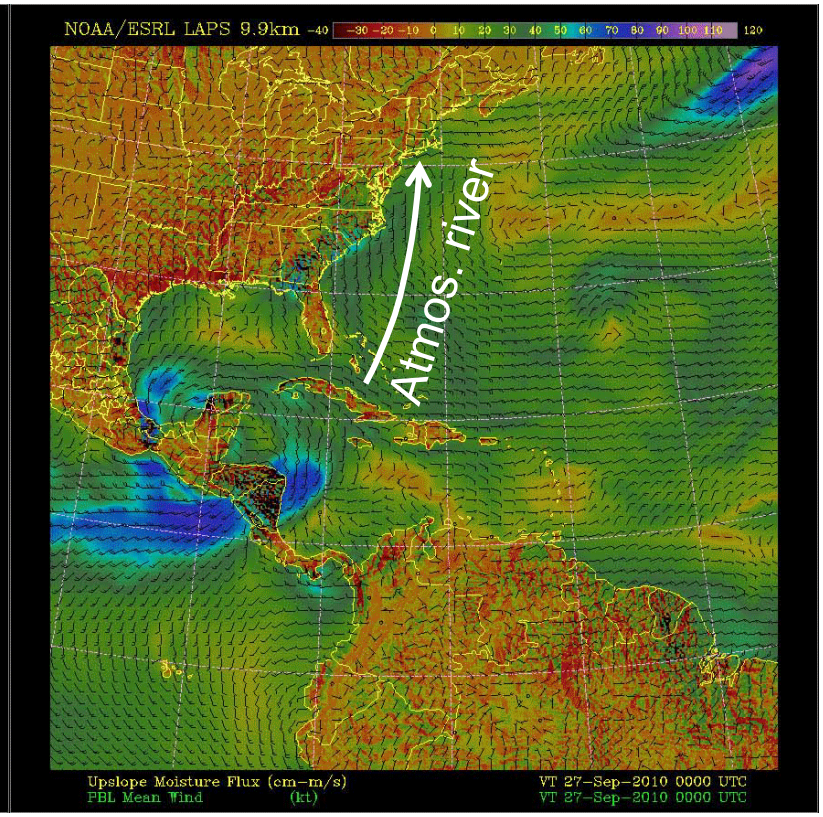


East Coast rain event spawned by TS Nicole late Sept. 2010
Local Analysis and Prediction System (LAPS; 9.9 km resolution)

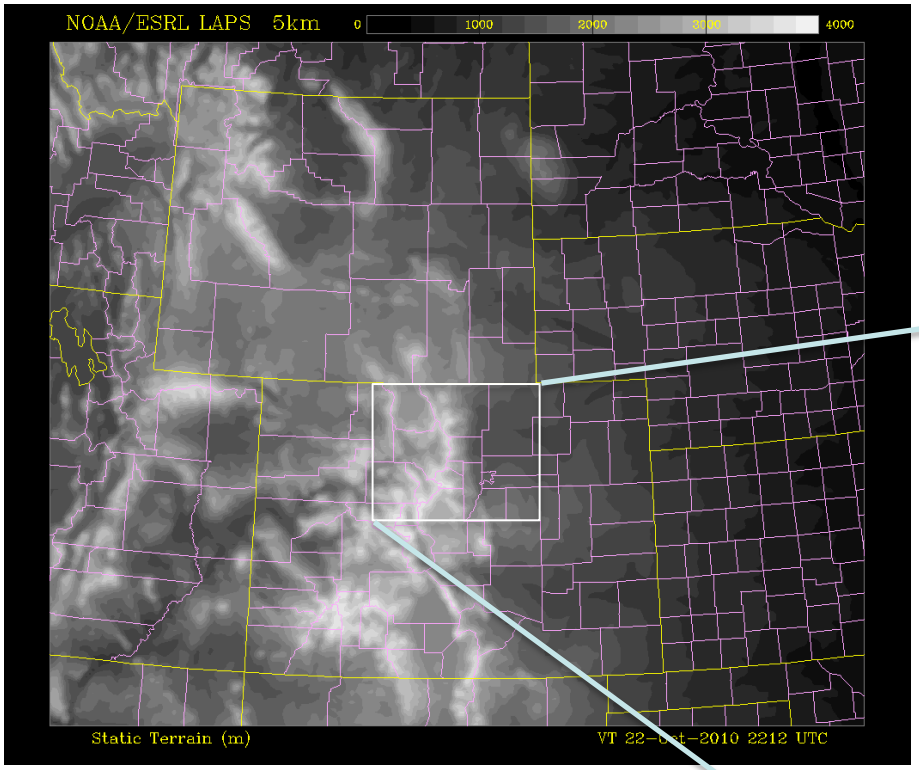
IPW (cm)



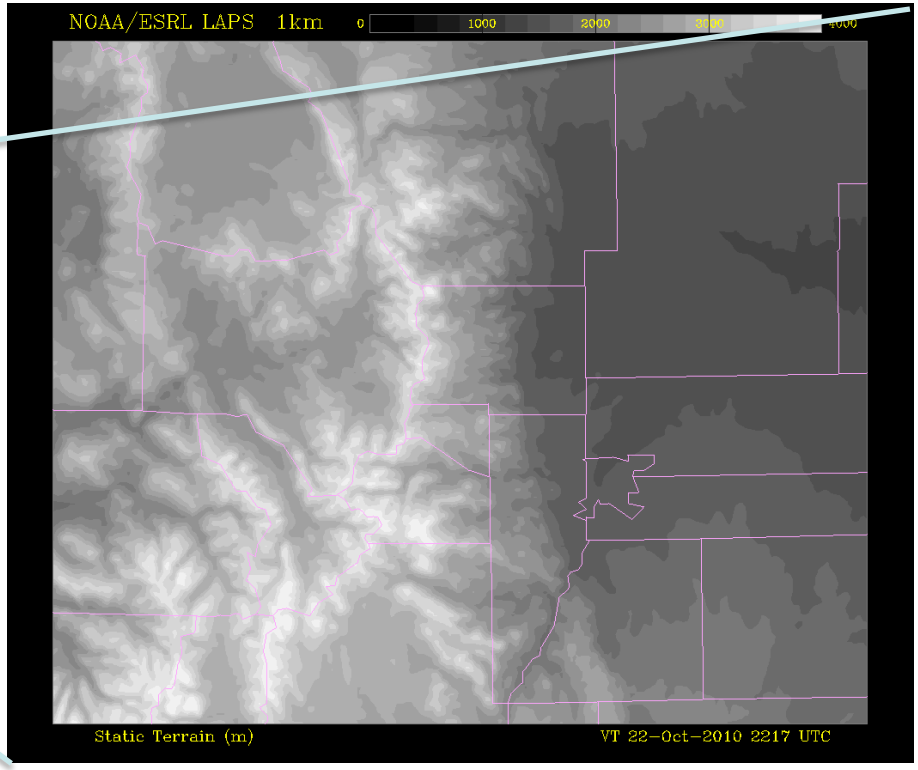
UM Flux (q x v) @ 1 km MSL



Representativeness of UMF depends on grid scale/topography resolution

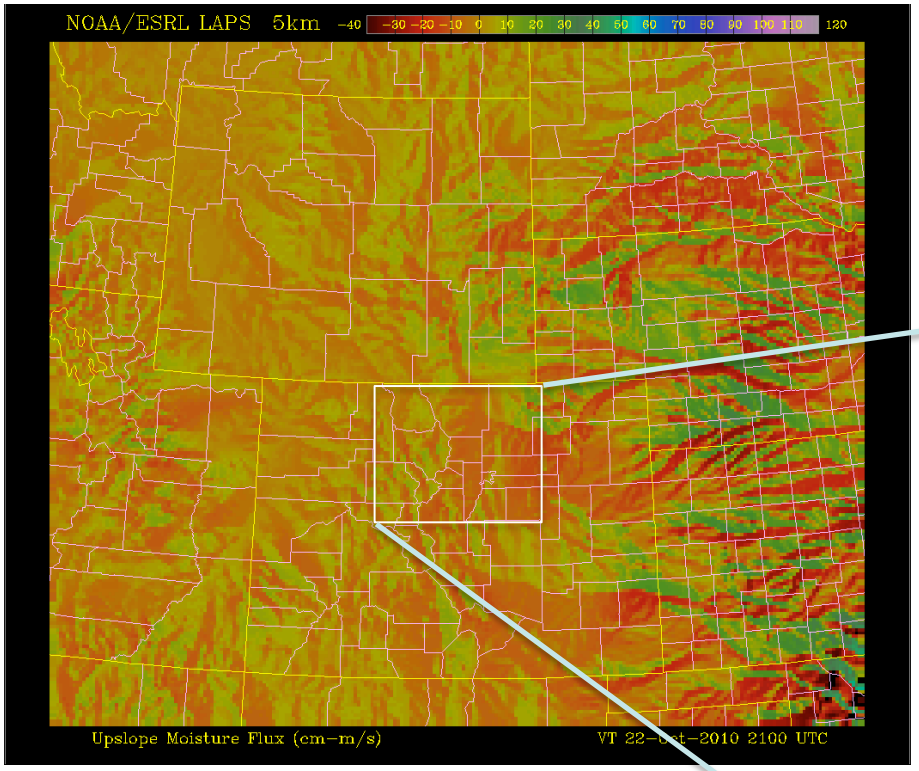


5 km grid terrain

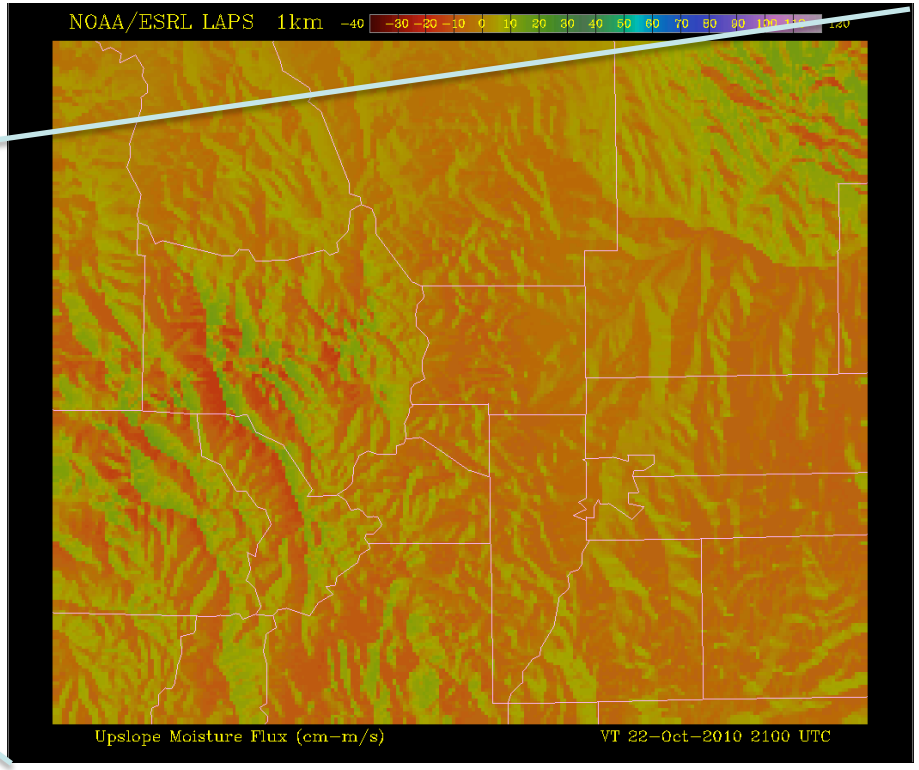


1 km grid terrain

Representativeness of UMF depends on grid scale/topography resolution



5 km grid UMF



1 km grid UMF

Prototype UMF Tool Status

Implemented via the LAPS lmfpost utility:

> Tested with LAPS, WRF-ARW, WRF-NNM

> Theoretically it will also work for RAMS & MM5, but this has not been tested

UMFLUX available via LAPS on-the-fly page:

http://laps.noaa.gov/request/nph-laps.cgi

> Source: analysis, Field: UMFLUX, Level: sfc/2d

HMT results available via: http://hmt.noaa.gov/

> Data > Archive

Conclusions

- Ongoing research has led to the creation of a real-time vapor-flux tool to monitor orographic rainfall forcing at multiple coastal sites.
- By combining observations and forecast model output, users can see how well a forecast model represents land-falling ARs and their resulting impacts on orographic rainfall enhancement.
- In the cases shown, the WRF model reasonably captured parts of the orographic forcing. However, the coastal and mountain rains were predicted poorly (*due to microphysics & terrain resolution?*).
- The three monitoring couplets deployed along the CA coast provided valuable lead time to forecasters for conditions leading to extreme rainfall.
- This capability has been implemented onto gridded domains via LAPS lfmpost, however representativeness will be on ongoing issue.